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**THE EFFECT OF JET FUEL EXPOSURE ON ADVANCED  
AEROSPACE COMPOSITES I: THERMAL AND CHEMICAL ANALYSIS**

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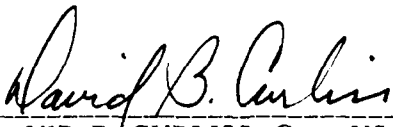
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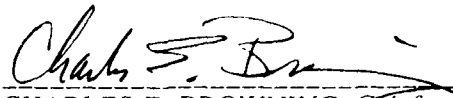
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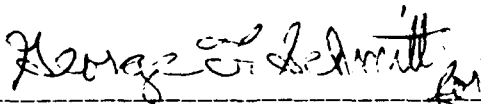


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13. ABSTRACT (Maximum 200 words) The sensitivity of several aerospace composite materials to military jet engine fuel, JP-4, was investigated in this study. The effect of fuel on the physical and mechanical properties was evaluated. The absorption rates of JP-4 into the composites and the effects of JP-4 exposure on the mechanical properties of the composites were given in WRDC-TR-90-4064. Thermal analysis of the composite materials including TMA and DSC was performed and is reported here. During exposure to JP-4, the only composite materials that absorbed an appreciable amount of fuel were the APC-2 [ $\pm 45$ ] <sub>2S</sub> and HTA [ $\pm 45$ ] <sub>2S</sub> coupons. Chemical species desorbed from these composite specimens using a vacuum desorption apparatus developed in-house were analyzed using GC-MS and the results are reported here. As expected, HTA and APC-2 coupons tested at elevated temperatures after exposure to JP-4 had lower levels of the more volatile components of JP-4 than did the HTA and APC-2 coupons exposed to JP-4 and tested at room temperature. The more volatile components are more mobile and more likely to desorb from the polymer at elevated temperatures. APC-2 was found to have significant quantities of Phenol present. This is attributed to the slightly polar character of the poly-(aryl ether ether ketone) (PEEK) matrix thermoplastic of APC-2.				
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## 1. INTRODUCTION

The design of structures utilizing advanced composite materials must not only consider mechanical requirements but must also account for the effect of the service environment on the material's performance. This consideration is especially important with organic polymer matrix composite materials, since the organic constituent will typically have much lower environmental resistance than conventional structural materials like steel, titanium, or aluminum. An environmental factor of concern is the fluid exposure that the composite part may be subjected to. Thermoplastic polymers may be of particular concern since they can, in theory, be completely dissolved by an appropriate solvent. Thermoset polymers, like epoxies, however, can only be swollen by solvents due to their cross-linked structure. In fact, densely crosslinked epoxies are very resistant to most common environmental fluids.

The concern with thermoplastic matrix composites is that many of the fluids with which they may come in contact are typically very good solvents for polymers. Paint strippers may contain benzene, phenol, or methylene chloride. Methyl-ethyl-ketone (MEK) may be used as a cleaning agent. Hydrocarbons in jet fuel are common fluids that will come in contact with the aircraft structure. Jet fuel is a complex mixture of hydrocarbons ranging in molecular weight from  $C_6$  to  $C_{14}$  alkanes/alkenes and a wide variety of aromatic compounds. Alkaline solutions are used to clean aircraft. In short, many fluids which may come into contact with the aircraft over its lifetime are of a concern from a solvent sensitivity prospective.

Thermoplastics that come into contact with fluids may react in several different ways. If the fluid is a good solvent for the polymer, it may induce immediate surface swelling and crazing and eventually completely dissolve the polymer. If the fluid is only a moderate or poor solvent for the polymer, it may only slowly

diffuse into the polymer without visible damage. In this case, the solvent fluid will become a plasticizing agent. This will cause the host polymer's glass transition temperature,  $T_g$ , to drop, thus reducing the composites maximum use temperature.

Paint strippers and cleaning fluids are typically very damaging to polymer matrix composites, but their usage is being restricted for health and environmental safety reasons. Jet fuel is a fluid that will always be in contact with the composite on a long term basis and at elevated temperatures. In addition, jet fuels are composed of many hydrocarbon components which are by themselves very good solvents for the thermoplastic polymers. For example, benzene, toluene, and ortho-, meta-, and para-xylene are present in significant concentrations in JP-4. Any of these solvents alone would be very detrimental to the thermoplastic matrix composite. Thus, the interest in evaluating the effect of JP-4 on composites stems from a concern of what effect the constituent fluids of JP-4 may have on the thermoplastic matrix polymer.

## 2. EXPERIMENTAL PROCEDURES

Preparation of the composite materials used in this study and exposure of the materials to JP-4 was reported in (1). The two analytic techniques discussed here are the thermal analysis and the solvent desorption.

### 2.1 Thermal Analysis

Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA), and Thermomechanical Analysis (TMA) were performed on each laminate produced and on specimens after exposure to JP-4. DSC was performed with a DuPont Model 910 DSC, TGA was performed with a DuPont Model 951 TGA, and TMA was performed with a DuPont Model 943 TMA. The DuPont equipment was controlled with an Omnitherm Advantage II IBM PS/2-60 data station. Sample size ranged from 5 mg to 15 mg for the DSC and TGA while the TMA used

specimens approximately 6mm X 6mm. TMA and TGA were performed under an inert atmosphere. All tests were performed at a standard heating rate of 10°C/min.

## 2.2 Desorption Analysis

A specially designed apparatus was used to extract and trap the components of jet fuel that were absorbed into the composite specimens. This apparatus is shown schematically in figure 1. The fuel exposed coupons were loaded into the sample chamber, and the entire apparatus volume is repeatedly purged with nitrogen and evacuated. In this way, the oxygen is effectively removed from the chamber to eliminate the possibility of oxidation of the hydrocarbon species. The chamber was heated to approximately 316°C and held for 1 hour. All volatiles from the coupons were collected in the cold trap. We found the desorption process to be quantitative and did not degrade the coupons, as the weight of the coupons after desorption was identical to their weight before exposure to JP-4. In addition, TGA experiments were carried out at these temperatures on control composite coupons to verify that no significant degradation would occur during the course of the desorption experiments. The condensate collected in the cold trap was diluted with spectrographic grade n-pentane and collected into a vial using a canula. The samples were then analyzed using GC-MS. This technique allows for separation of the components in the mixture (GC) and their identification (MS). The technique was also used to qualitatively determine the relative amount of each component in the mixture. This was done by taking a ratio of the peak area of the components to some reference peak. The problem with this technique is that the n-pentane solvent peak was of different concentration from sample to sample. In some cases, the n-pentane concentration overwhelmed the desorbed components, thus the error in the amount of the individual components was greater than in cases when components concentration relative to n-pentane was greater.

### 3. EXPERIMENTAL RESULTS

#### 3.1 Thermal Analysis Results

The thermal analysis performed on the control specimens was used primarily for quality assurance, verifying that the Tg, crystallization temperature (Tc), and endotherm peaks were all characteristic of the materials evaluated. Thermal analysis on the fuel exposed specimens was performed to detect changes in Tg and phase transitions. As shown in WRDC-TR-90-4064, none of the unidirectional (0° or 90°) composite specimens absorbed an appreciable amount of any jet fuel components, and there are no significant changes in their DSC, TMA, or TGA scans. The only significant changes noted in the composites were in their  $\pm 45^\circ$  laminates.

##### 3.1.1 Differential Scanning Calorimetry

Figures 2 through 10 are the DSC scans available for the control and jet fuel exposed  $\pm 45^\circ$  laminates. Figures 2 and 3 are the DSC data for the APC-2 control and JP-4 exposed coupons, respectively. The APC-2 DSC scan did have a larger heat of crystallization for the  $\pm 45^\circ$  laminate configuration exposed to jet fuel than for the  $\pm 45^\circ$  control coupon. TGA-MS results have indicated that there is a large volatile evolution that occurs with the crystallization transition. This could contribute to what appears to be a larger heat of crystallization. Figures 4 and 5 are the DSC data for the IM8/HTA control and JP-4 exposed specimens respectively. The IM8/HTA DSC data indicate that the Tg has decreased from 250°C in the control coupon to approximately 210°C in the jet fuel exposed coupon. Figures 6 and 7 are the DSC data for the AS4/3501-6 control and JP-4 exposed specimens respectively. No change is apparent in the DSC evaluation of the AS4/3501-6 specimens. Figures 8 and 9 are the DSC data for the IM7/8551-7A control and JP-4 exposed specimens respectively. The AS4/3501-6 DSC data indicate, no apparent change in the DSC results for the IM7/8551-

7A between the control and the specimen exposed to JP-4. Figures 10 and 11 are the DSC data for the IM7/977-2 control and JP-4 exposed specimens respectively. The control specimen has a Tg of 209°C while the specimen exposed to JP-4 has a Tg of 183°C. These specimens also exhibit a large exotherm beginning at approximately 300°C. This is presumably due to further reaction.

### 3.1.2 Thermomechanical Analysis

The TMA measurements were made with an expansion probe. The data thus indicate the linear thermal expansion out of the plane of the  $\pm 45^\circ$  laminate. Inflections, or changes in slope, between the glassy and rubbery region is one method of determining the Tg of a polymeric solid or polymer matrix composite material. Figures 12 through 23 are TMA scans available for the  $\pm 45^\circ$  control coupons and those exposed to JP-4. Figures 12 and 13 are the TMA data for the APC-2 control and JP-4 exposed coupons respectively. The control coupon exhibits a Tg inflection at approximately 139°C while the coupon exposed to JP-4 exhibits a Tg inflection at approximately 120°C. As reported earlier (WRDC-TR-90-4064), the  $\pm 45^\circ$  APC-2 laminate did absorb a significant amount of JP-4. It is likely that the absorbed solvent acted as a plasticizer to lower the Tg of the matrix. Figures 14 and 15 are the TMA data for the IM8/HTA control and JP-4 exposed coupons respectively. The control IM8/HTA specimen had a Tg of 258°C, and the specimen exposed to JP-4 had a Tg of 240°C. This is consistent with the view that selective components of the JP-4 are plasticizing the matrix polymer of the composite. Figures 16 and 17 are the TMA data for the AS4/3501-6 control and JP-4 exposed coupons respectively. The AS4/3501-6 has two apparent transitions on the TMA scan data. The maxima that are indicated on the figures are taken as the Tg of the material. The control has a Tg of approximately 190°C, and the specimen exposed to JP-4 has a Tg of approximately 180°C. However, an inflection appears in the data prior to these maxima on each curve. Although not marked on the figures, this inflection was determined to be at 168°C for the

control AS4/3501-6 specimen and at 134°C for the specimen exposed to JP-4. Regardless of the transition used to determine the Tg of the 3501-6 matrix composite, the Tg is at least 10°C lower after exposure to JP-4. Figures 18 and 19 are the TMA data for the IM7/8551-7A control and JP-4 exposed coupons respectively. The control coupon in this case had a Tg inflection at 200°C while the coupon exposed to JP-4 had a Tg inflection at approximately 185°C. This is approximately the same reduction in Tg as measured in the 3501-6 system. Figures 20 and 21 are the TMA data for the IM7/977-2 control and JP-4 exposed composite coupons. The control coupon has a Tg inflection at 177°C, and the coupon exposed to JP-4 has a Tg of approximately 175°C, indicating very low sensitivity to the JP-4 exposure. This was confirmed by the In-Plane Shear data presented in WRDC-TR-90-4064. The G<sub>12</sub> for IM7/977-2 exposed to JP-4 did not differ greatly as a function of temperature from the control coupons. Figures 22 and 23 are the TMA data for the IM7/5250-4 control and JP-4 exposed composite coupons. The Tg for the control occurs at 252°C and at 249°C for the coupons exposed to JP-4. The Tg inflections are very distinct and provide a good indication that the toughened BMI is not sensitive to the JP-4 exposure.

### 3.2 GC-MS Desorption Results

The two thermoplastic matrix composites in this study were the only materials that absorbed any significant quantity of fuel, thus these two thermoplastic matrix composites were the only ones analyzed by desorption and GC-MS. In addition, control JP-4 and JP-8 specimens were analyzed as a basis for comparison. Figures 24 through 29 are the GC elution traces for the cases indicated in table 1. The MS identification results and quantitative analysis data are given in tables 2 through 7.

The analysis of the control fuel samples agrees with typical lab analysis of these fuels. Jet fuels are a very complex mixture of hydrocarbons over a wide range of molecular weights from

approximately C<sub>6</sub> to C<sub>14</sub>. The JP-4 in general has higher concentrations of the lower molecular weight species than the JP-8 fuel. We can make two basic observations from the data. The first is that the fuel samples desorbed from specimens tested at elevated temperatures (250°F for APC-2 and 350°F for HTA) tend to have lower concentrations of the lower molecular weight species. This is consistent with the basic tenets of phase equilibrium thermodynamics that the more volatile species will diffuse out of the polymer more readily than will the higher molecular weight species. The second observation is that APC-2 contains significant amounts of more polar hydrocarbon derivatives, such as phenol, than does HTA. This is presumably due to specific chemical interactions between the solvent dipole and the dipole along the polymer backbone.

#### 4. CONCLUSIONS

To conclude, the results of physical and chemical characterization of this series of advanced composites were as expected: the thermoplastic matrix composites absorbed more than the densely crosslinked thermosetting materials, and the absorbed species were primarily the low molecular weight aromatic derivatives. The absorption appears to be reversible without notable degradation of the matrix polymer. There is no evidence that any component of the matrix polymers is leaching into the jet fuel or that any fraction of the polymers is dissolving into the jet fuel. Further work is needed to determine long-term effects of exposure of thermoplastic matrix composites to jet fuel under more realistic simulated conditions.

#### 5. REFERENCES

1. Curliss, D.B. and D.M. Carlin, "The effect of Jet Fuel Exposure on Advanced Aerospace Composites II: Mechanical Properties," WRDC-TR-90-4064, 1990.

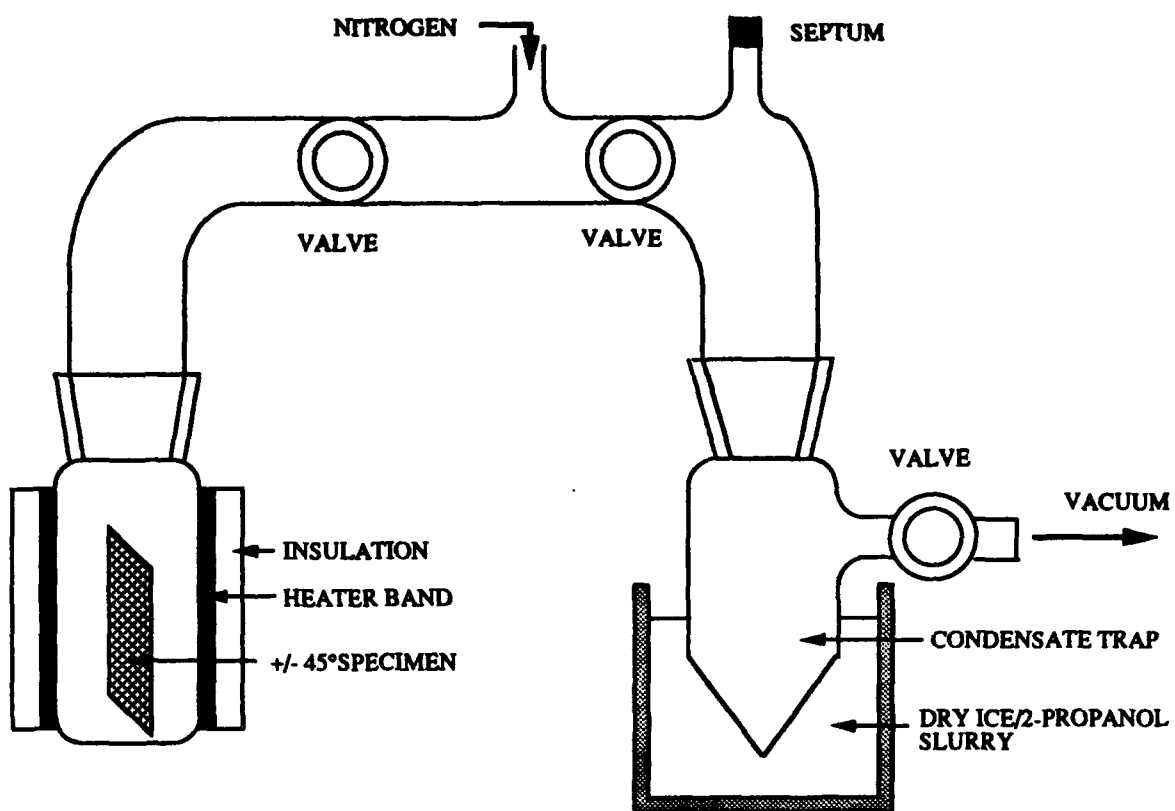


Figure 1. Schematic diagram of vacuum desorption apparatus.



# DSC (GRN)

OMNITHERM ATAVANTAGE II

SAMPL ID : APC2/AS4  
 RUN ID : 1537  
 SIZE : 7.100 mg  
 OPERATOR: W.A. PRICE

DATE RUN: Sep/23/1989  
 GAS 1 : NIT  
 GAS 2 : AIR  
 COMMENT : PEEK +/- 45

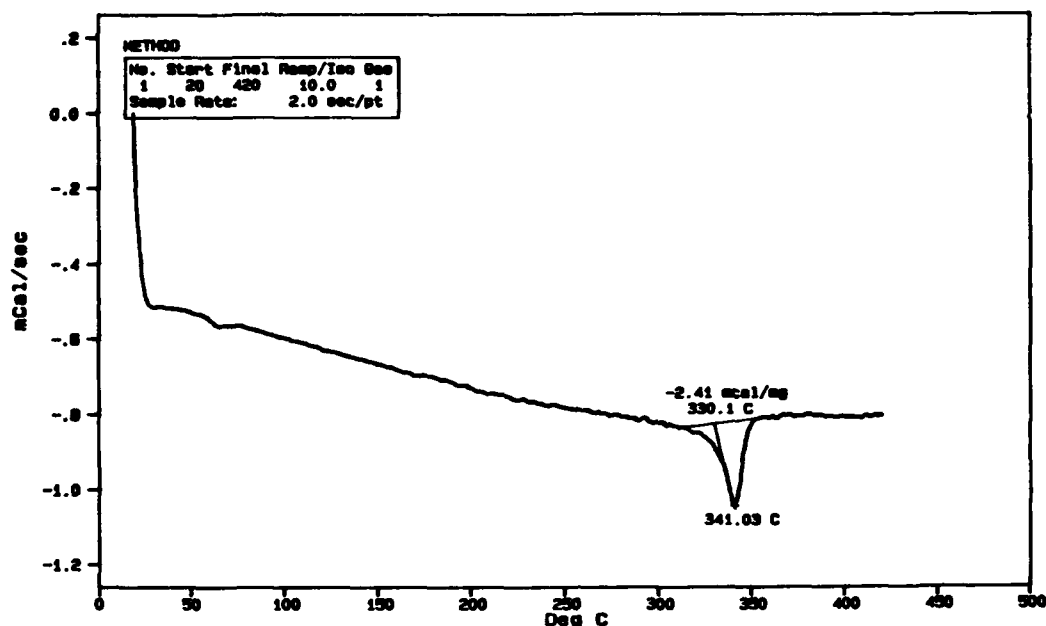


Figure 2. DSC data of ±45 APC-2 control specimen

# DSC (GRN)

OMNITHERM ATAVANTAGE II

SAMPL ID : APC2/AS4  
 RUN ID : 1804  
 SIZE : 12.100 mg  
 OPERATOR: W.A. PRICE

DATE RUN: Nov/13/1989  
 GAS 1 : NITROGEN  
 GAS 2 : AIR  
 COMMENT : EXPOSED TO JP-4

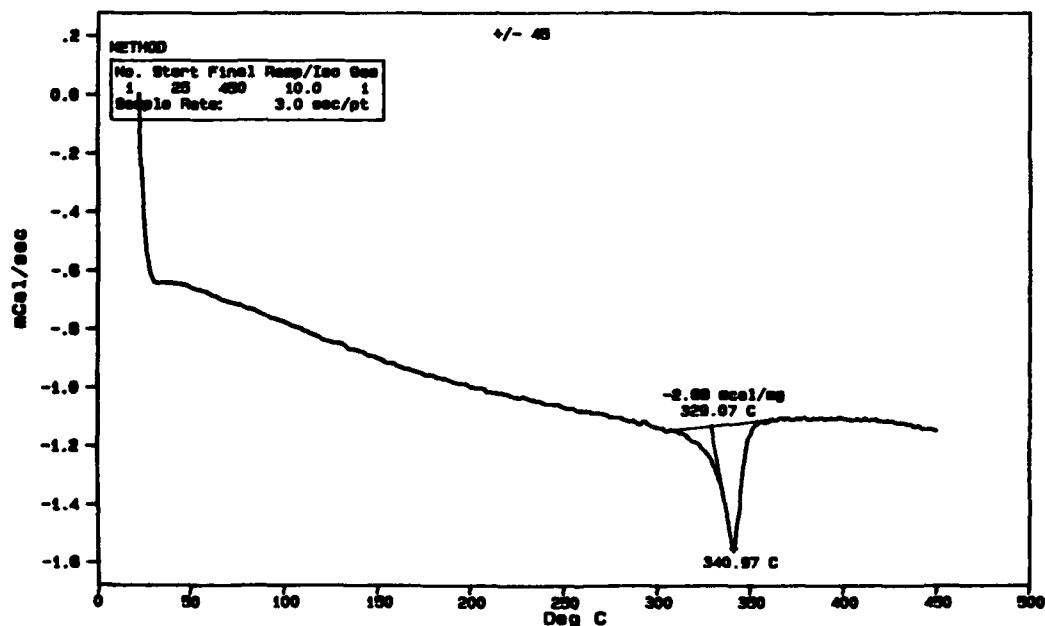


Figure 3. DSC data of ±45 APC-2 JP-4 exposed specimen

DSC (GRN)  
OMNITHERM ADVANTAGE II

SAMPL ID : HTA/IM8  
RUN ID : 1549  
SIZE : 15.400 mg  
OPERATOR: W.A. PRICE

DATE RUN: Sep/24/1989  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : +/- 45 PAN 1

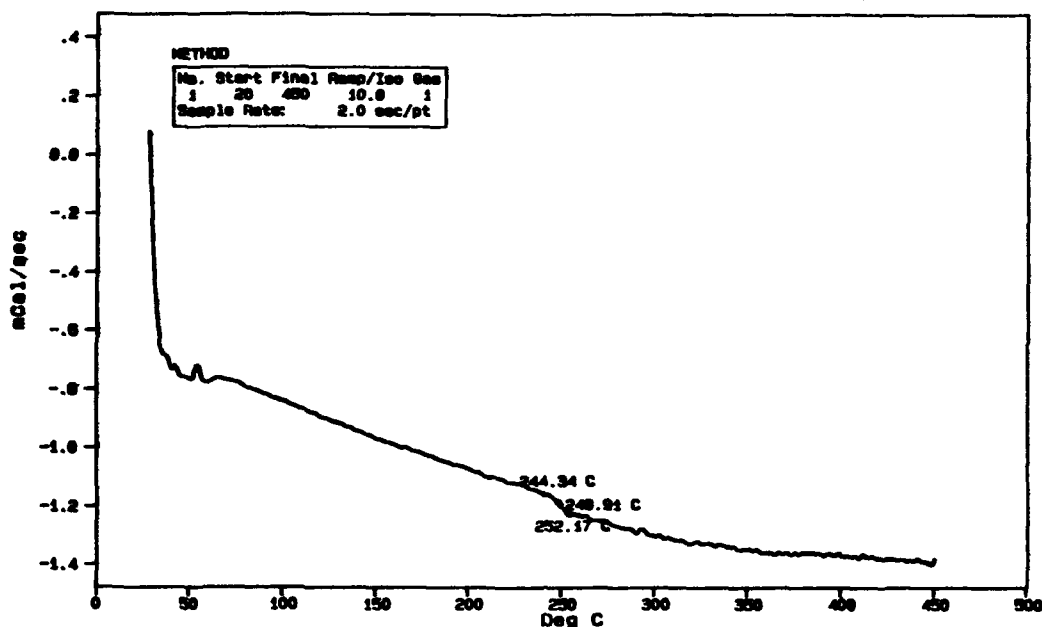


Figure 4. DSC data of  $\pm 45$  IM8/HTA control specimen

DSC (GRN)  
OMNITHERM ADVANTAGE II

SAMPL ID : HTA/IM8  
RUN ID : 1802  
SIZE : 15.700 mg  
OPERATOR: W.A. PRICE

DATE RUN: Nov/13/1989  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

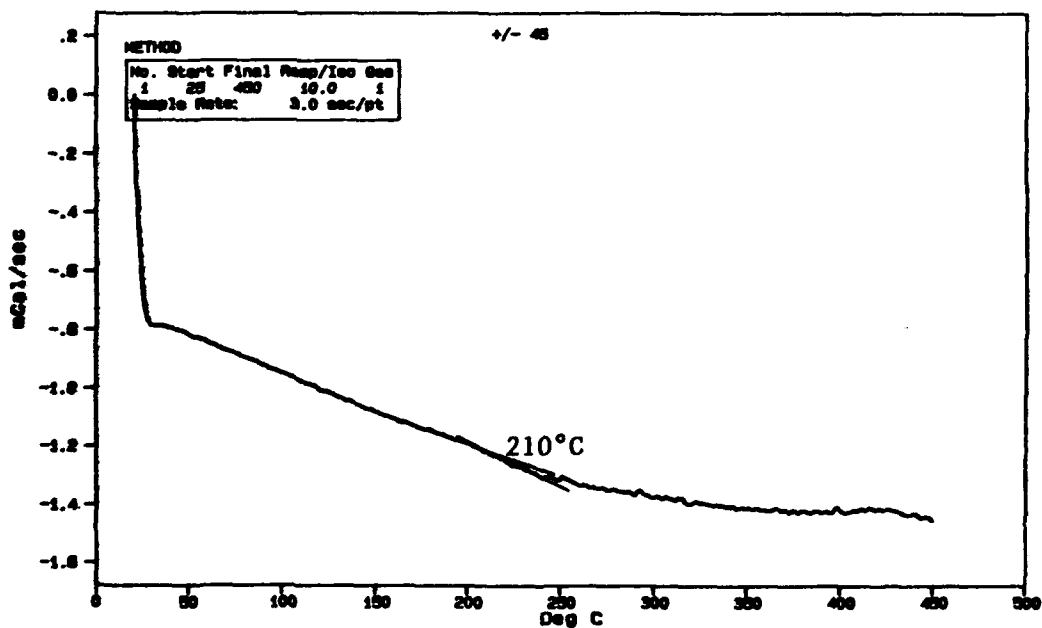


Figure 5. DSC data of  $\pm 45$  IM8/HTA JP-4 exposed specimen

DSC (GRN)  
OMNITHERM ATVANTAGE II

SAMPLE ID : 3501-6/AS4  
RUN ID : 1540  
SIZE : 15.100 mg  
OPERATOR: W.A. PRICE

DATE RUN: Sep/23/1989  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : +/- 45 VAC OVEN

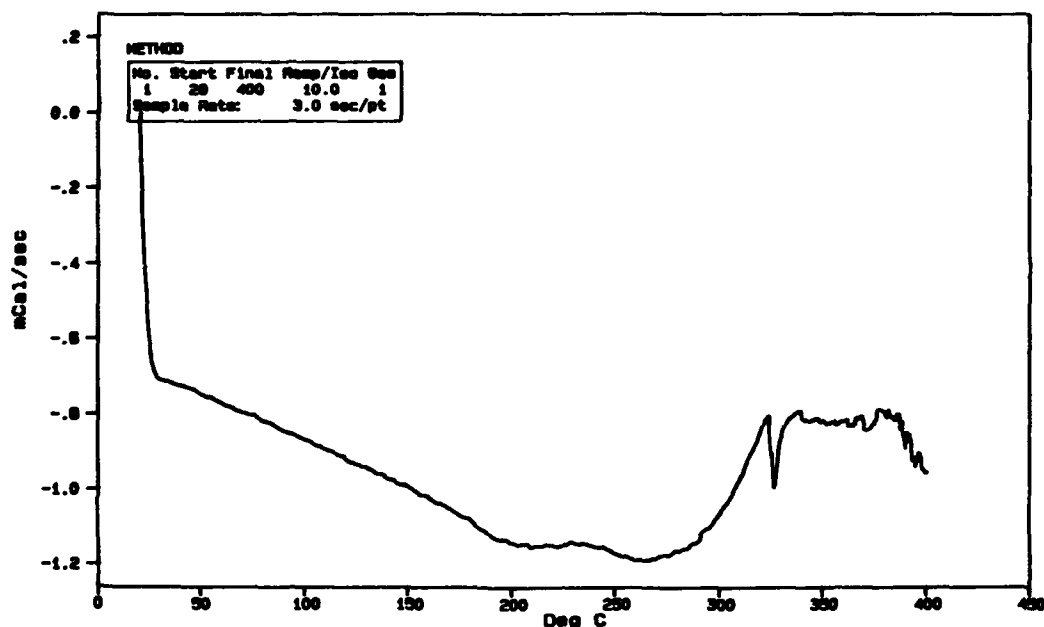


Figure 6. DSC data of  $\pm 45$  AS4/3501-6 control specimen

DSC (GRN)  
OMNITHERM ATVANTAGE II

SAMPLE ID : 3501-6/AS4  
RUN ID : 1612  
SIZE : 16.200 mg  
OPERATOR: W.A. PRICE

DATE RUN: Nov/14/1989  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

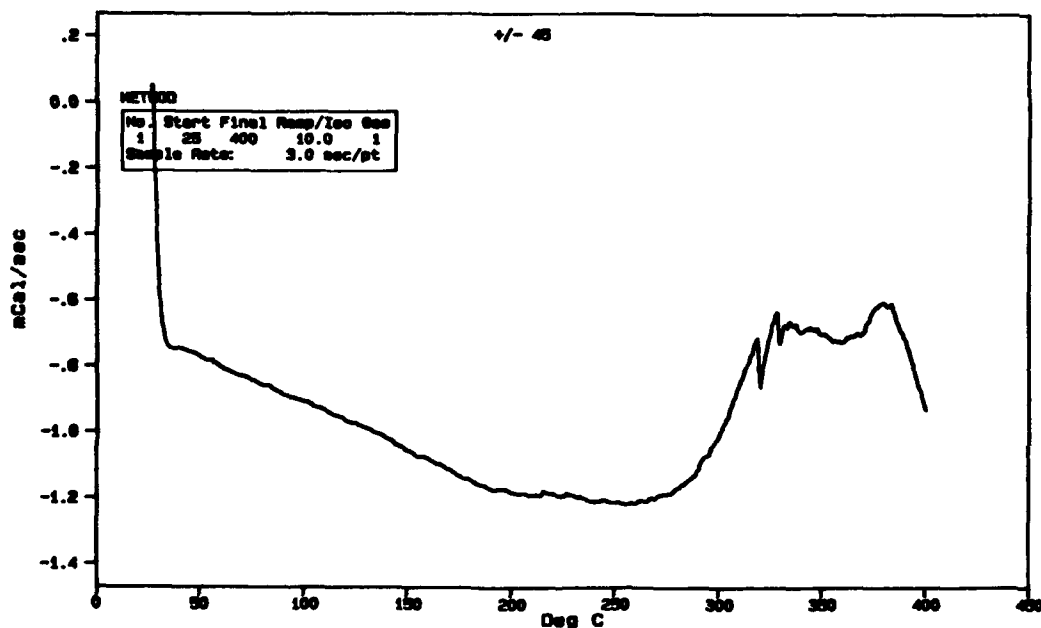


Figure 7. DSC data of  $\pm 45$  AS4/3501-6 JP-4 exposed specimen

DSC (GRN)  
OMNITHERM ADVANTAGE II

SAMPL ID : 8551-7A/IM7  
RUN ID : 1548  
SIZE : 9.100 mg  
OPERATOR: W.A. PRICE

DATE RUN: Sep/24/1989  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : +/- 45

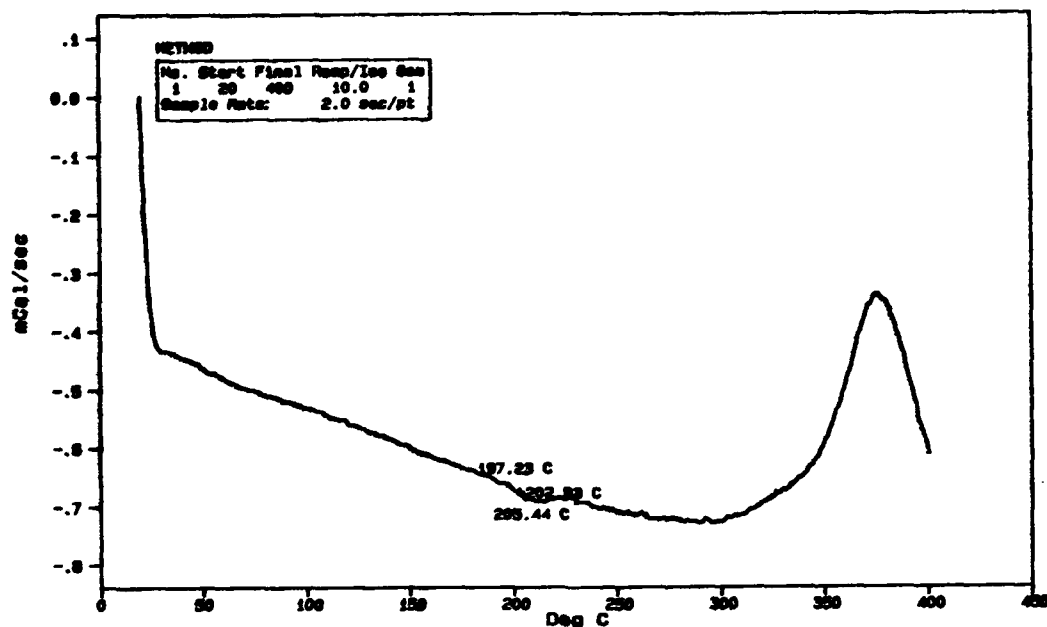


Figure 8. DSC data of  $\pm 45$  IM7/8551-7A control specimen

DSC (GRN)  
OMNITHERM ADVANTAGE II

SAMPL ID : 8551-7A/IM7  
RUN ID : 1608  
SIZE : 10.600 mg  
OPERATOR: W.A. PRICE

DATE RUN: Nov/14/1989  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

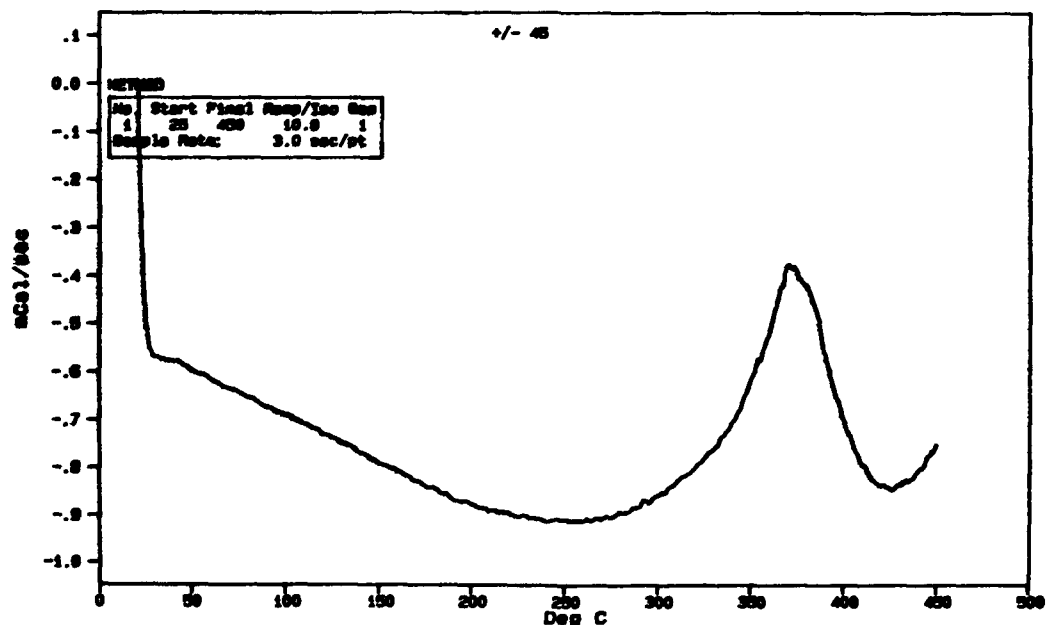


Figure 9. DSC data of  $\pm 45$  IM7/8551-7A JP-4 exposed specimen

DSC (GRN)  
OMNITHERM ATAVANTAGE II

SAMPL ID : 977/IM7  
RUN ID : 1561  
SIZE : 8.200 mg  
OPERATOR: W.A. PRICE

DATE RUN: Sep/26/1989  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : 90

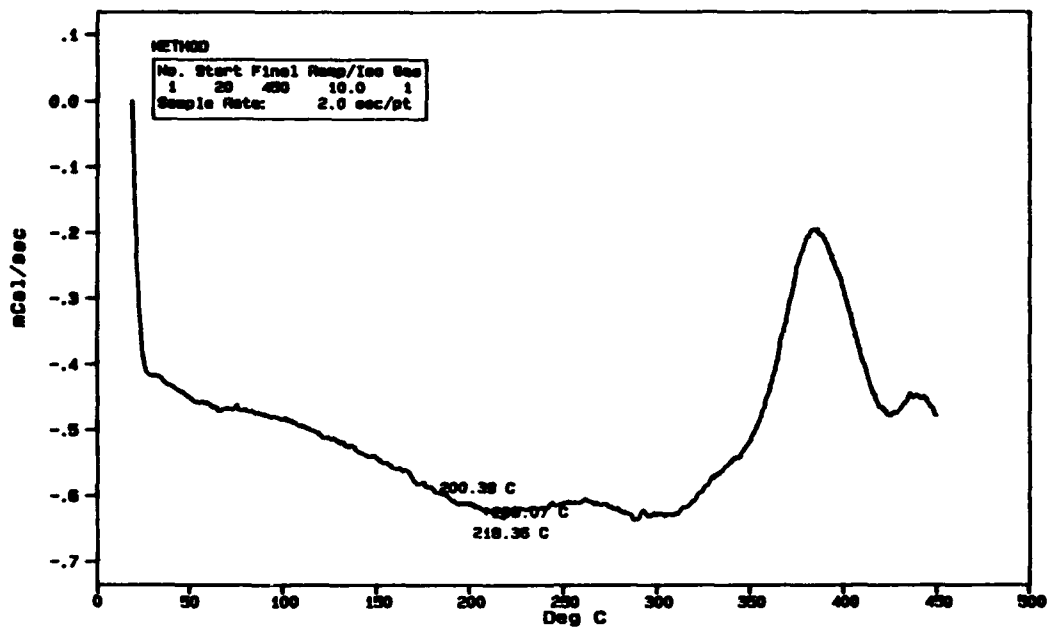


Figure 10. DSC data of  $\pm 45$  IM7/977-2 control specimen

DSC (GRN)  
OMNITHERM ATAVANTAGE II

SAMPL ID : 977-2/IM7  
RUN ID : 1606  
SIZE : 11.800 mg  
OPERATOR: W.A. PRICE

DATE RUN: Nov/14/1989  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

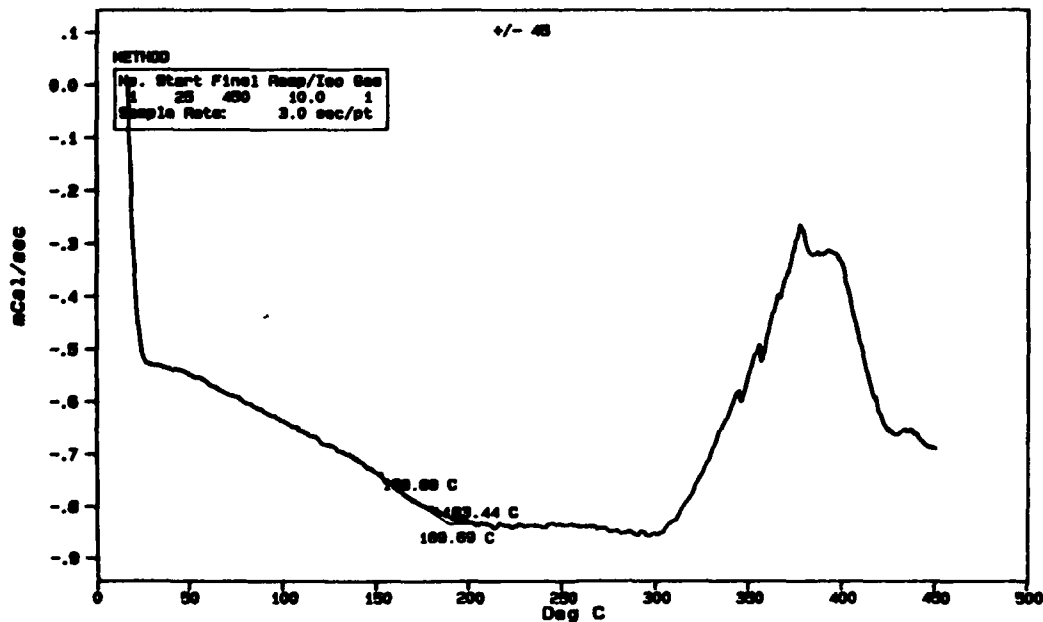


Figure 11. DSC data of  $\pm 45$  IM7/977-2 JP-4 exposed specimen

TMA 800  
OMNITHERM ATAVANTAGE II

SAMPL ID : APC2/AS4  
RUN ID : 1538  
SIZE : .900 mm  
OPERATOR: W.A. PRICE

DATE RUN: Sep/23/1989  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : PEEK +/- 45

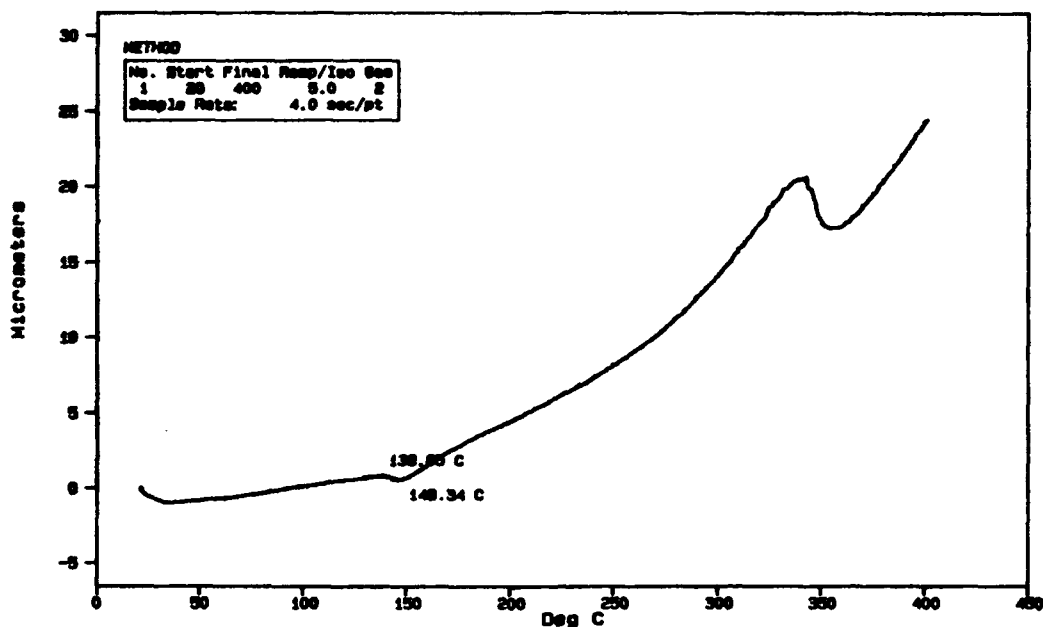


Figure 12. TMA data of  $\pm 45$  APC-2 control specimen

TMA 800  
OMNITHERM ATAVANTAGE II

SAMPL ID : APC2/AS4  
RUN ID : 1803  
SIZE : .800 mm  
OPERATOR: W.A. PRICE

DATE RUN: Nov/13/1989  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

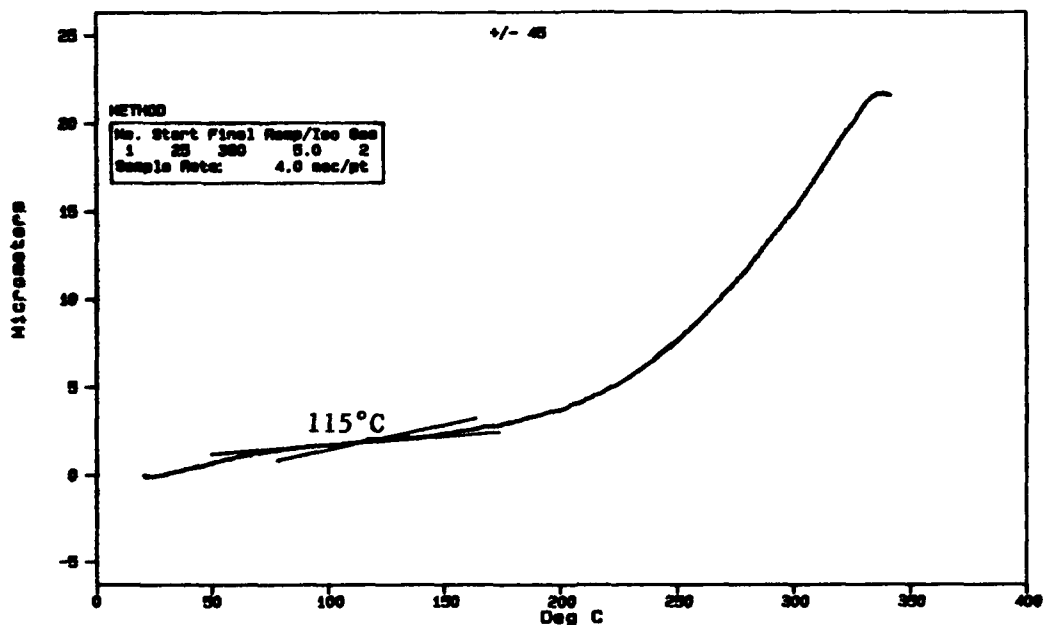


Figure 13. TMA data of  $\pm 45$  APC-2 JP-4 exposed specimen

TMA 800  
OMNITHERM ADVANTAGE II

SAMPLE ID : HTA/IM8  
RUN ID : 1550  
SIZE : 1.020 mm  
OPERATOR: W.A. PRICE

DATE RUN: Sep/24/1989  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : +/- 45 PAN 1

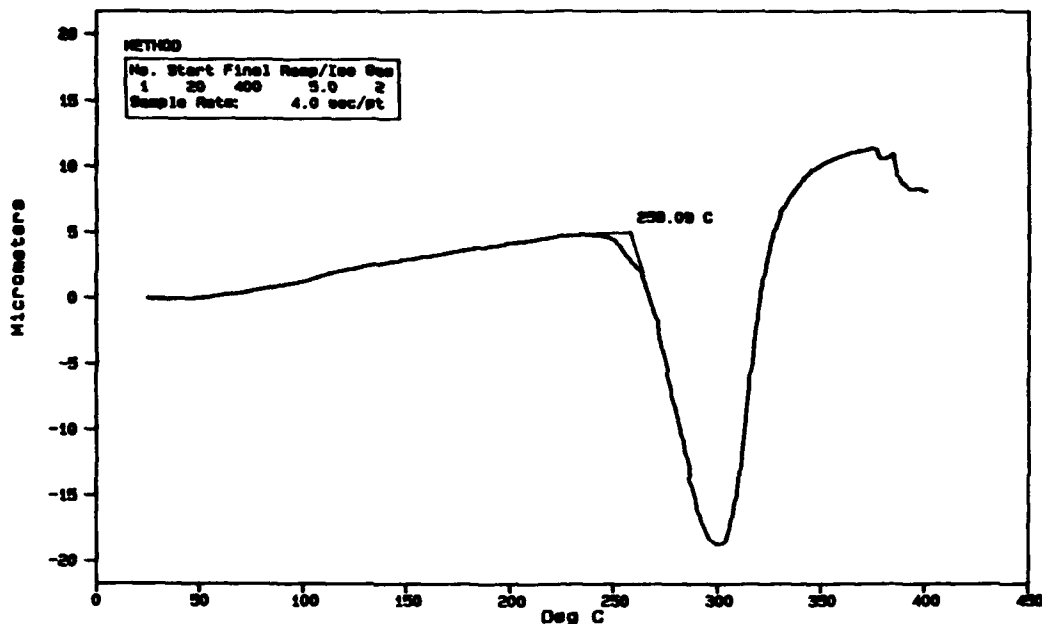


Figure 14. TMA data of  $\pm 45$  IM8/HTA control specimen

TMA 800  
OMNITHERM ADVANTAGE II

SAMPLE ID : HTA/IM8  
RUN ID : 1600  
SIZE : 3.200 mm  
OPERATOR: W.A. PRICE

DATE RUN: Nov/13/1989  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

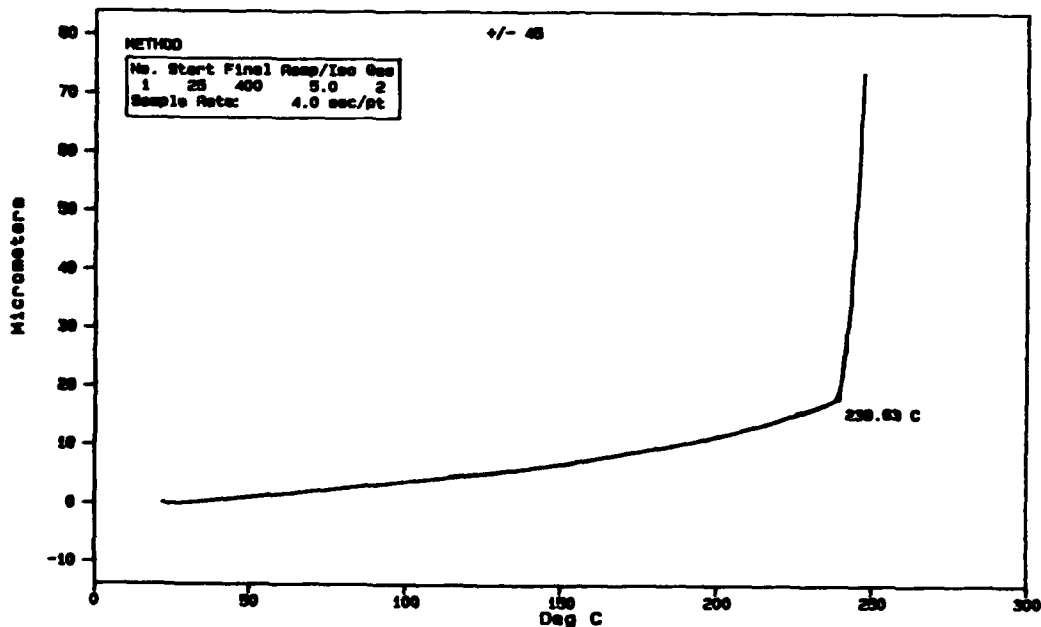


Figure 15. TMA data of  $\pm 45$  IM8/HTA JP-4 exposed specimen

TMA 800  
OMNITHERM ATVANTAGE II

SAMPL ID : 3501-6/AS4  
RUN ID : 1541  
SIZE : 1.050 mm  
OPERATOR: W.A. PRICE

DATE RUN: Sep/23/1989  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : +/- 45 VAC OVEN

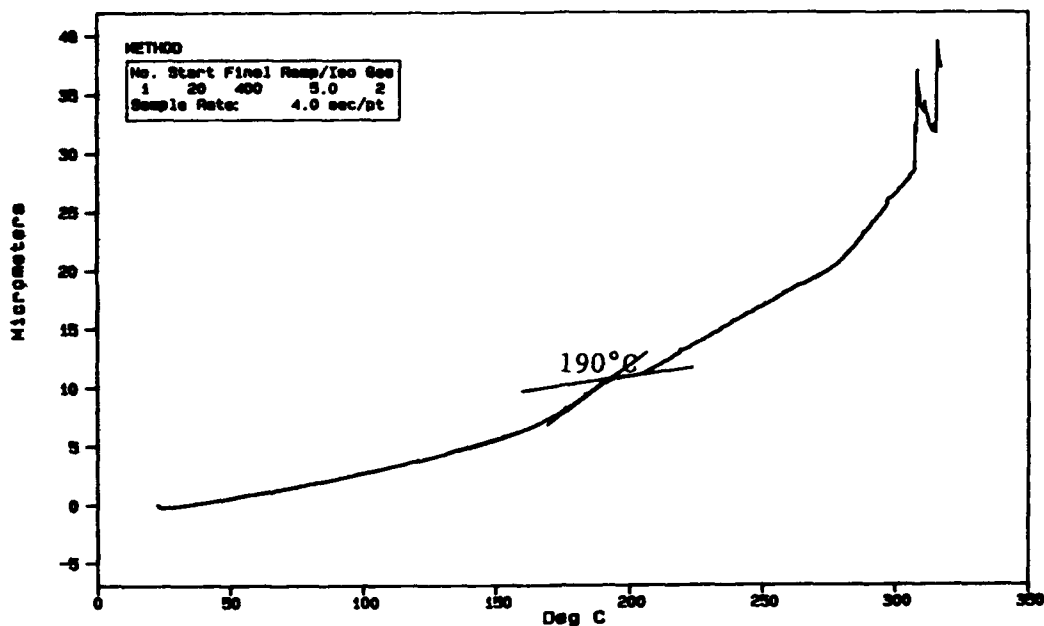


Figure 16. TMA data of  $\pm 45$  AS4/3501-6 control specimen

TMA 800  
OMNITHERM ATVANTAGE II

SAMPL ID : 3501-6/AS4  
RUN ID : 1611  
SIZE : 1.140 mm  
OPERATOR: W.A. PRICE

DATE RUN: Nov/14/1989  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

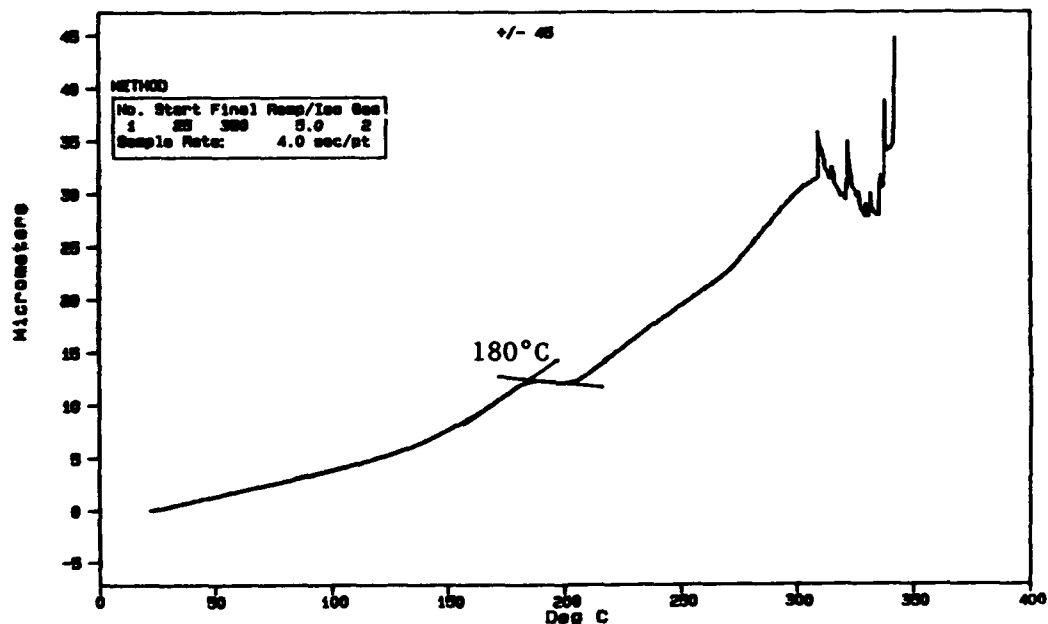


Figure 17. TMA data of  $\pm 45$  AS4/3501-6 JP-4 exposed specimen



TMA 800  
OMNITHERM ATVANTAGE II

SAMPL ID : 8551-7A/IM7  
RUN ID : 1565  
SIZE : 1.490 mm  
OPERATOR: W.A. PRICE

DATE RUN: Sep/29/1999  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : 90

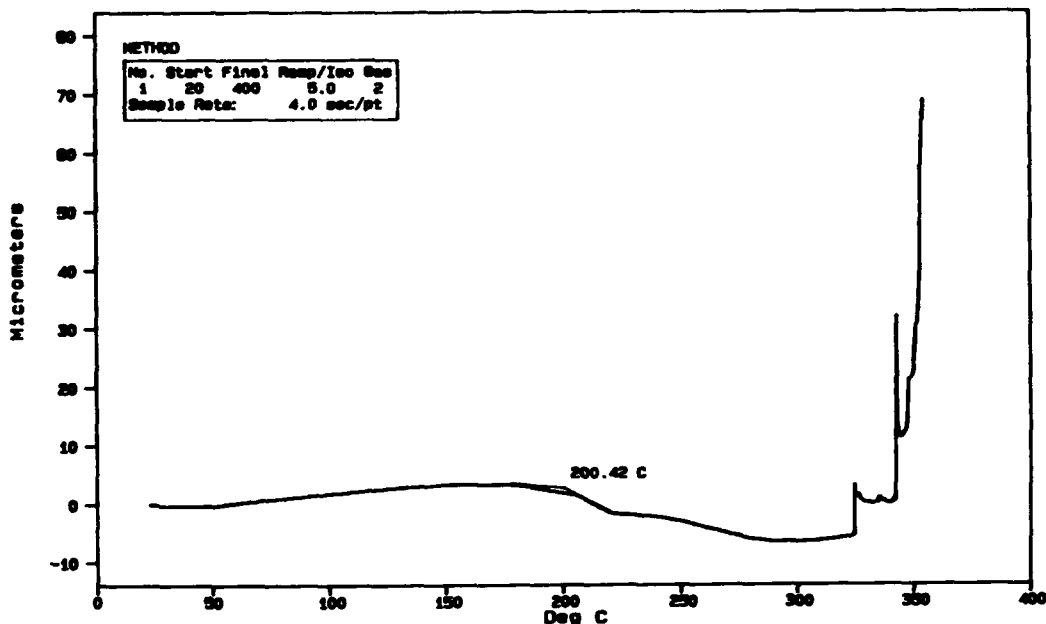


Figure 18. TMA data of  $\pm 45$  IM7/8551-7A control specimen

TMA 800  
OMNITHERM ATVANTAGE II

SAMPL ID : 8551-7A/IM7  
RUN ID : 1607  
SIZE : 1.065 mm  
OPERATOR: W.A. PRICE

DATE RUN: Nov/14/1999  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

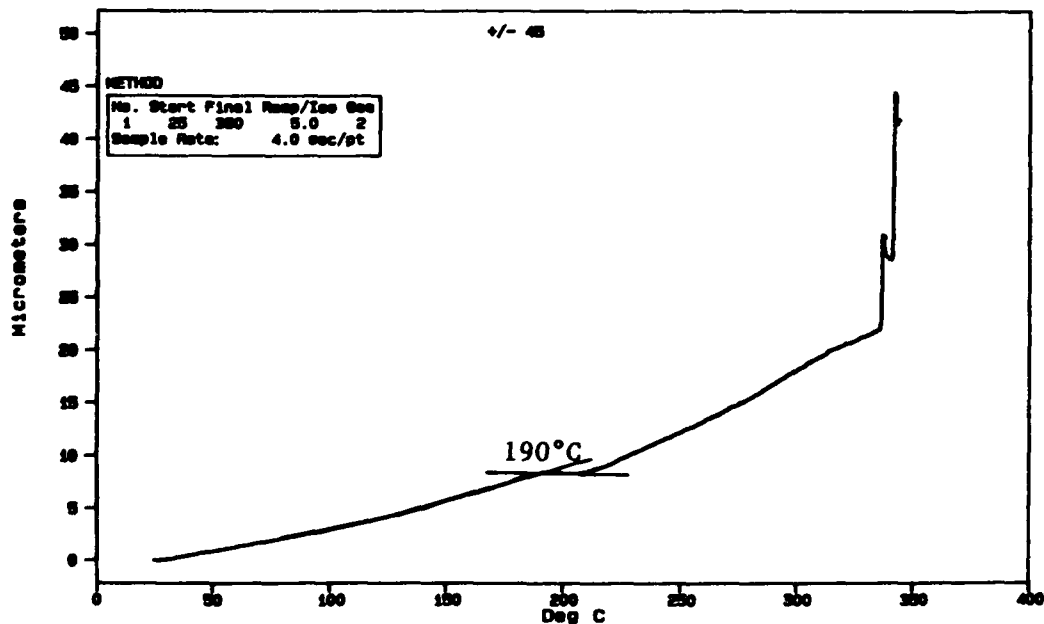


Figure 19. TMA data of  $\pm 45$  IM7/8551-7A JP-4 exposed specimen

TMA 800  
OMNITHERM ATVANTAGE II

SAMPL ID : 977/IM7  
RUN ID : 1562  
SIZE : 1.580 mm  
OPERATOR: W.A. PRICE

DATE RUN: Sep/26/1989  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : 90

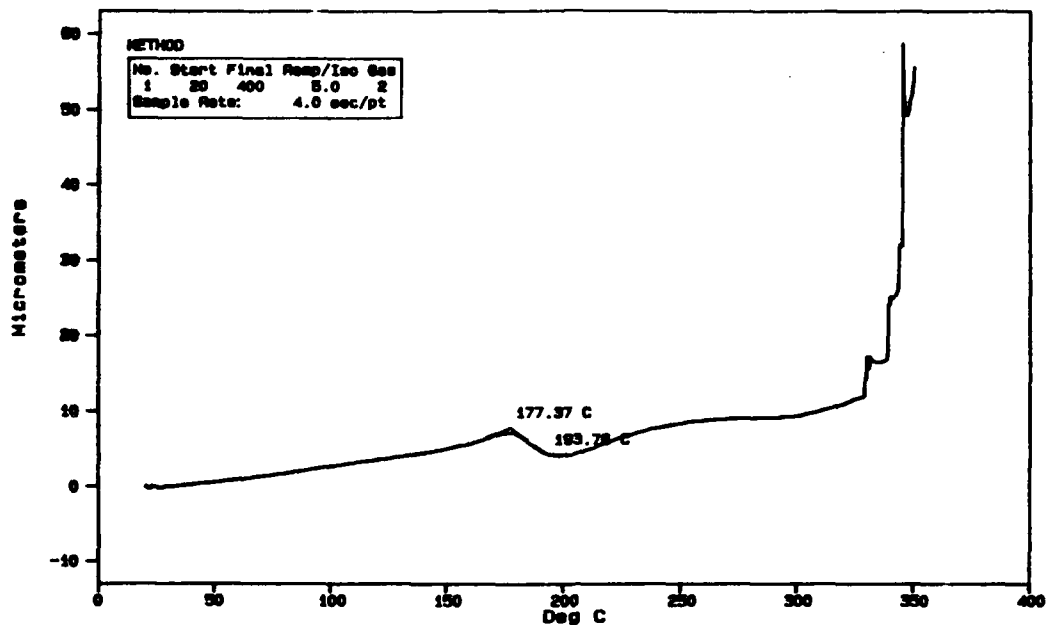


Figure 20. TMA data of  $\pm 45$  IM7/977-2 control specimen

TMA 800  
OMNITHERM ATVANTAGE II

SAMPL ID : 977-2/IM7  
RUN ID : 1805  
SIZE : 1.090 mm  
OPERATOR: W.A. PRICE

DATE RUN: Nov/14/1989  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

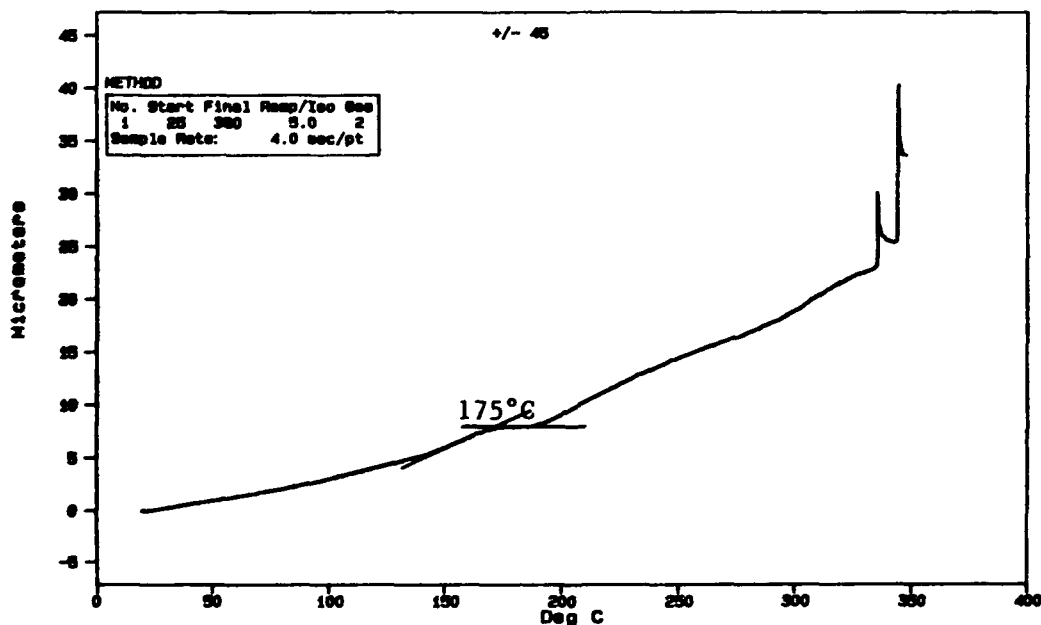


Figure 21. TMA data of  $\pm 45$  IM7/977-2 JP-4 exposed specimen

**TMA 800**  
OMNITHERM ADVANTAGE II

SAMPLE ID : 5250-4/IM7  
RUN ID : 1544  
SIZE : 1.000 mm  
OPERATOR: W.A. PRICE

DATE RUN: Sep/23/1989  
GAS 1 : NIT  
GAS 2 : AIR  
COMMENT : +/- 45

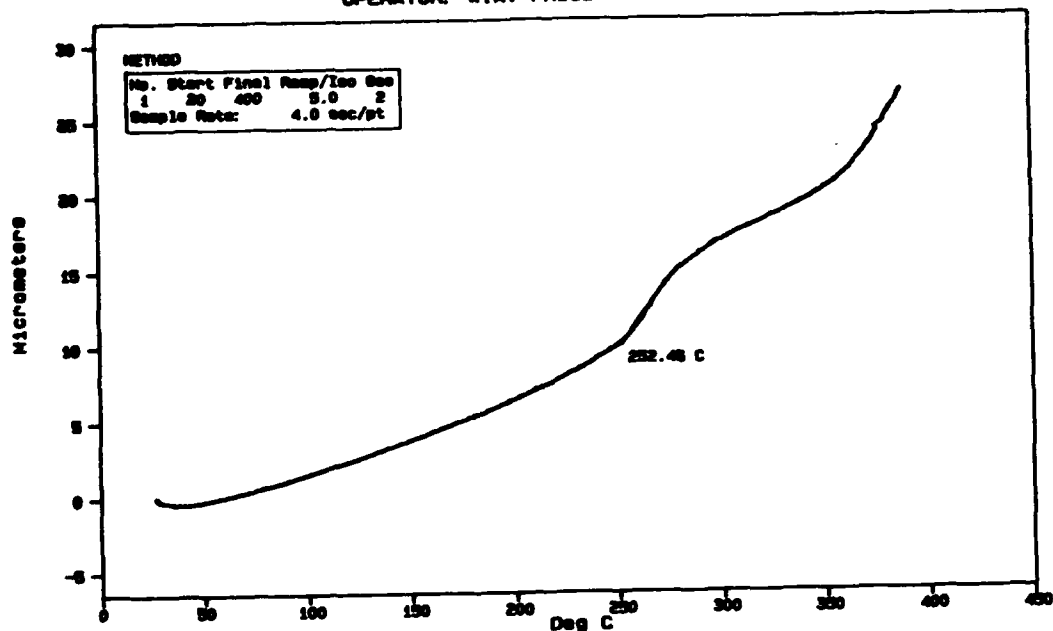


Figure 22. TMA data of  $\pm 45$  IM7/5250-4 control specimen

**TMA 800**  
OMNITHERM ADVANTAGE II

SAMPLE ID : 5250-4/IM7  
RUN ID : 1609  
SIZE : 1.040 mm  
OPERATOR: W.A. PRICE

DATE RUN: Nov/14/1989  
GAS 1 : NITROGEN  
GAS 2 : AIR  
COMMENT : EXPOSED TO JP-4

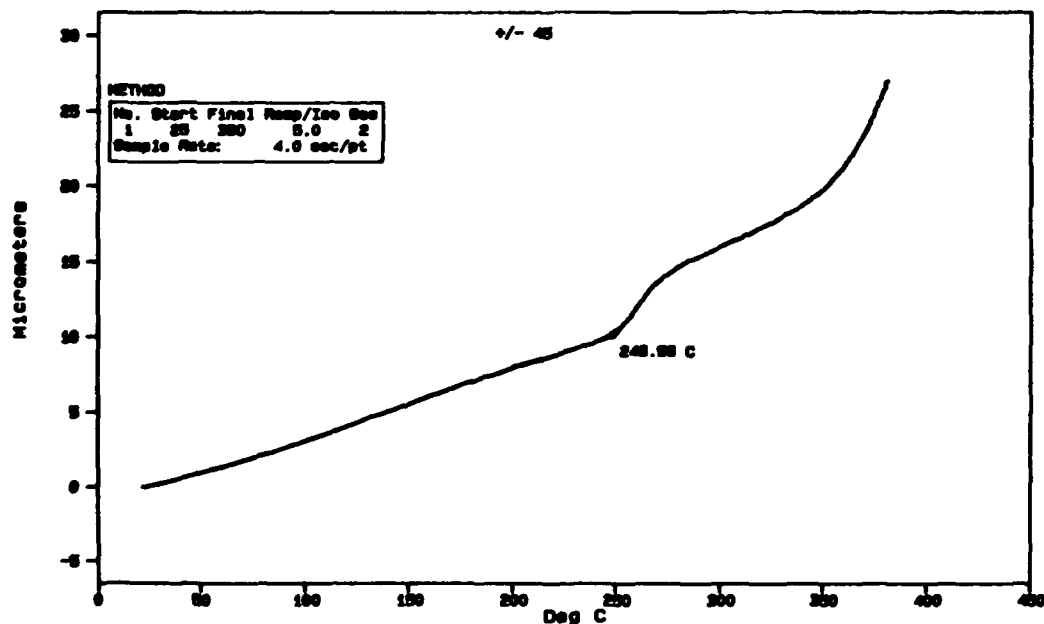


Figure 23. TMA data of  $\pm 45$  IM7/5250-4 JP-4 exposed specimen

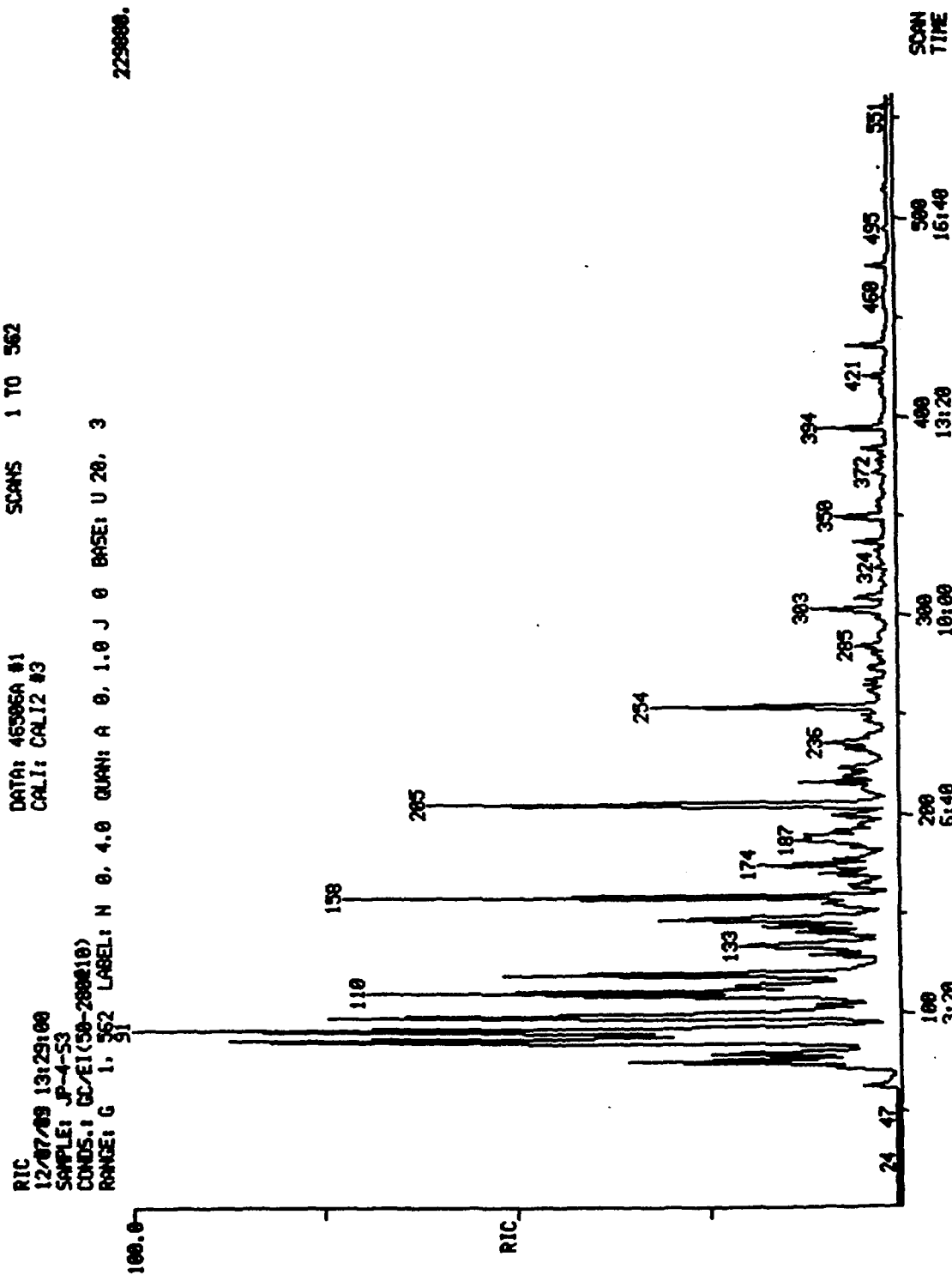


Figure 24. GC data for JP-4 sample

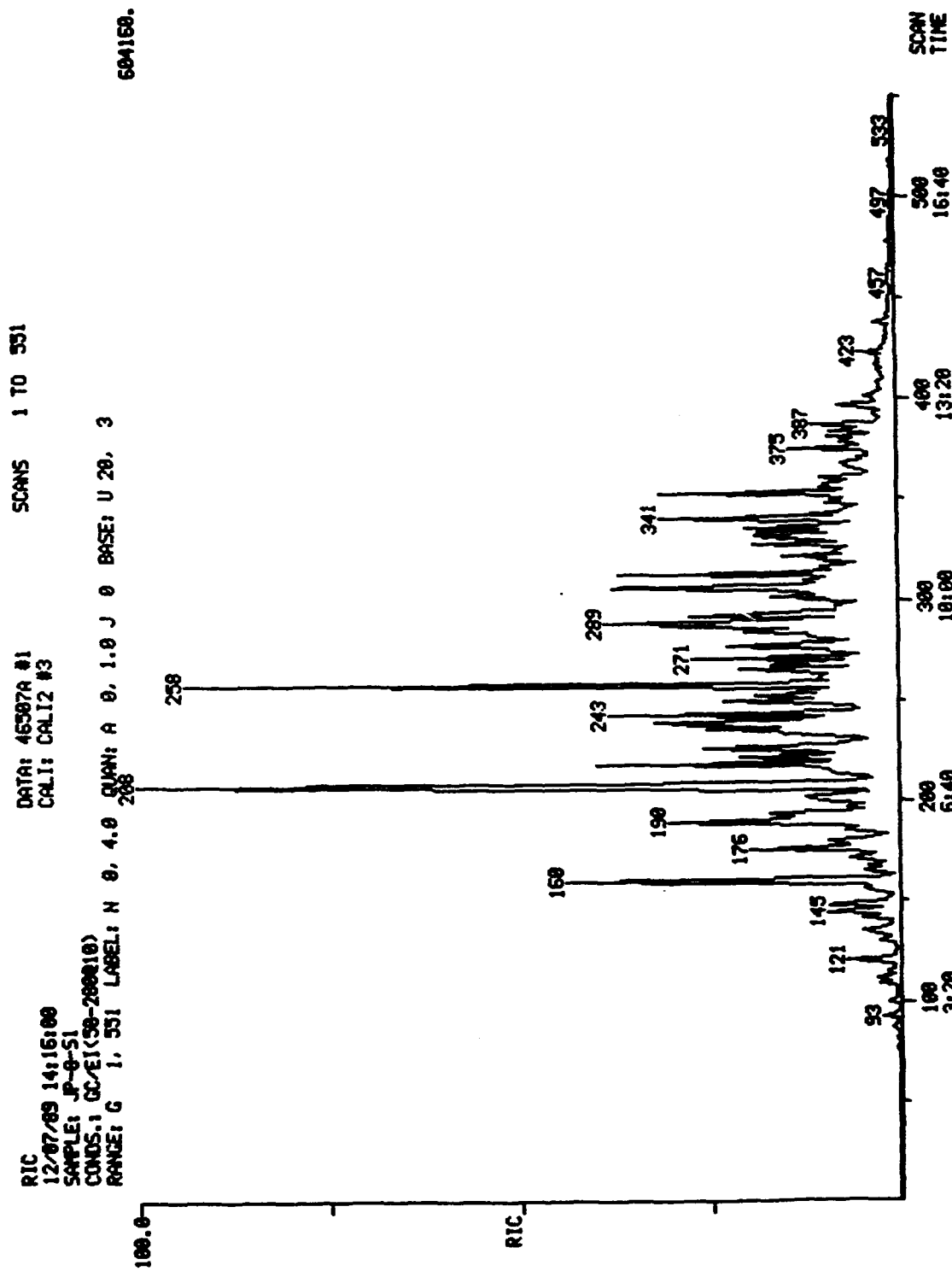


Figure 25. GC data for JP-8 sample

RIC  
 01/28/98 14:54:00  
 SAMPLE: ATP-R745  
 CONDS.: GC/EI(50-200210)  
 RANGE: G 1.511 LABEL: N 0.4.0 QUAN: A 0.1.0 J 0 BASE: U 20. 3  
 DATA: 46966A #393  
 CALI: CAL12 #3  
 SCANS 1 TO 511  
 766976.

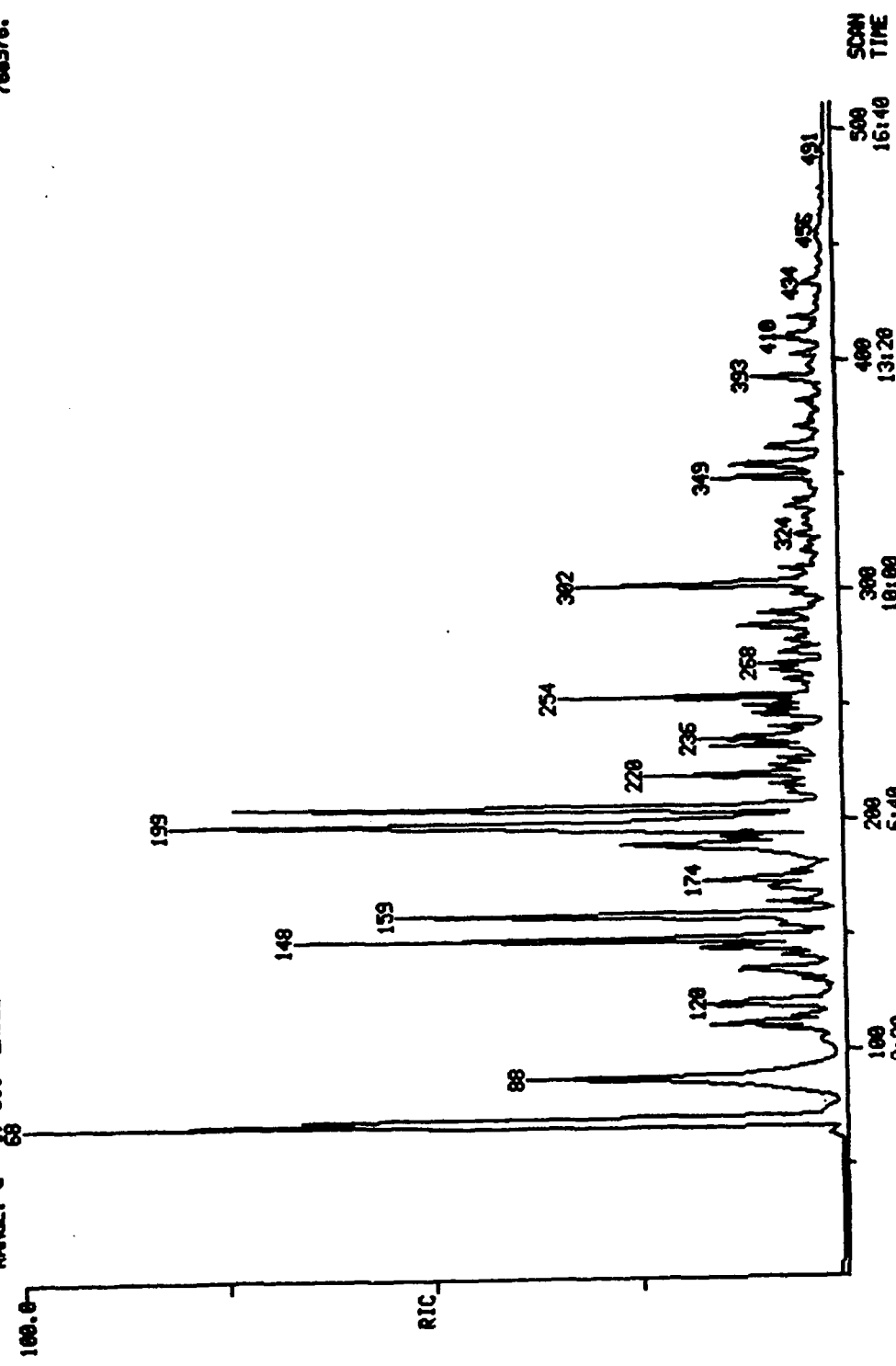


Figure 26. GC data for sample from APC-2, tested at RT

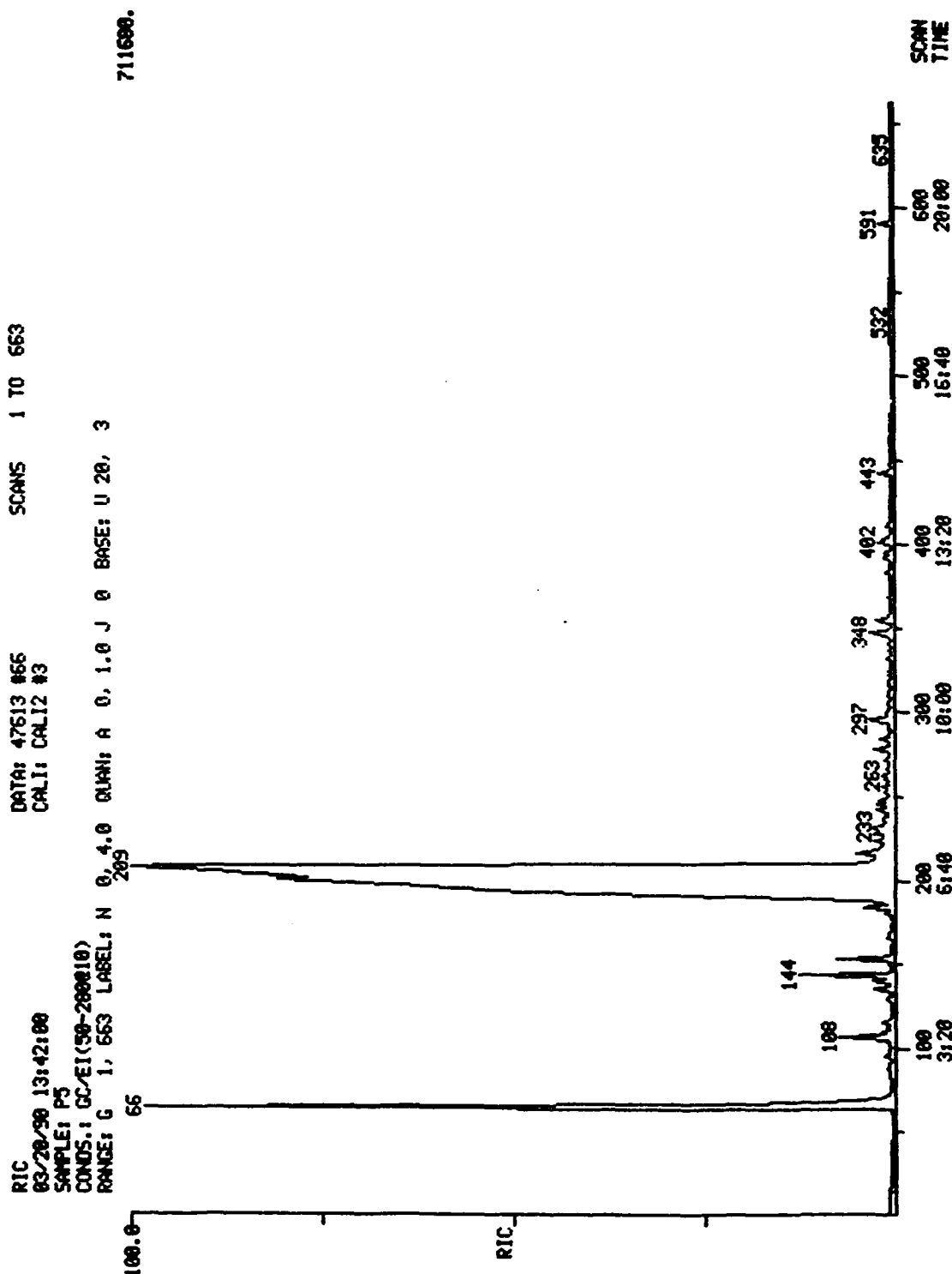


Figure 27. GC data for sample from APC-2, tested at 250°F

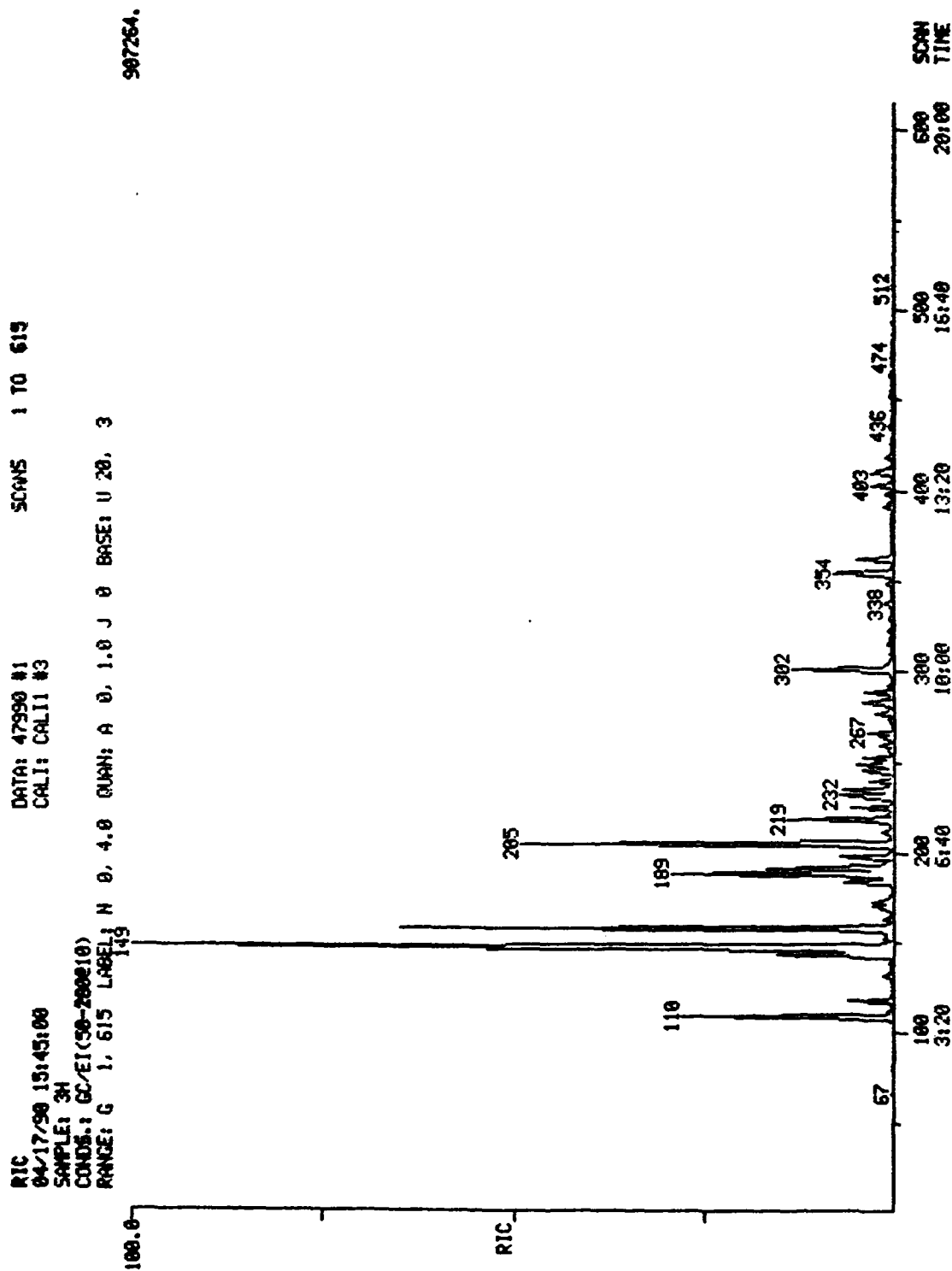


Figure 28. GC data for sample from IM8/HTA, tested at RT



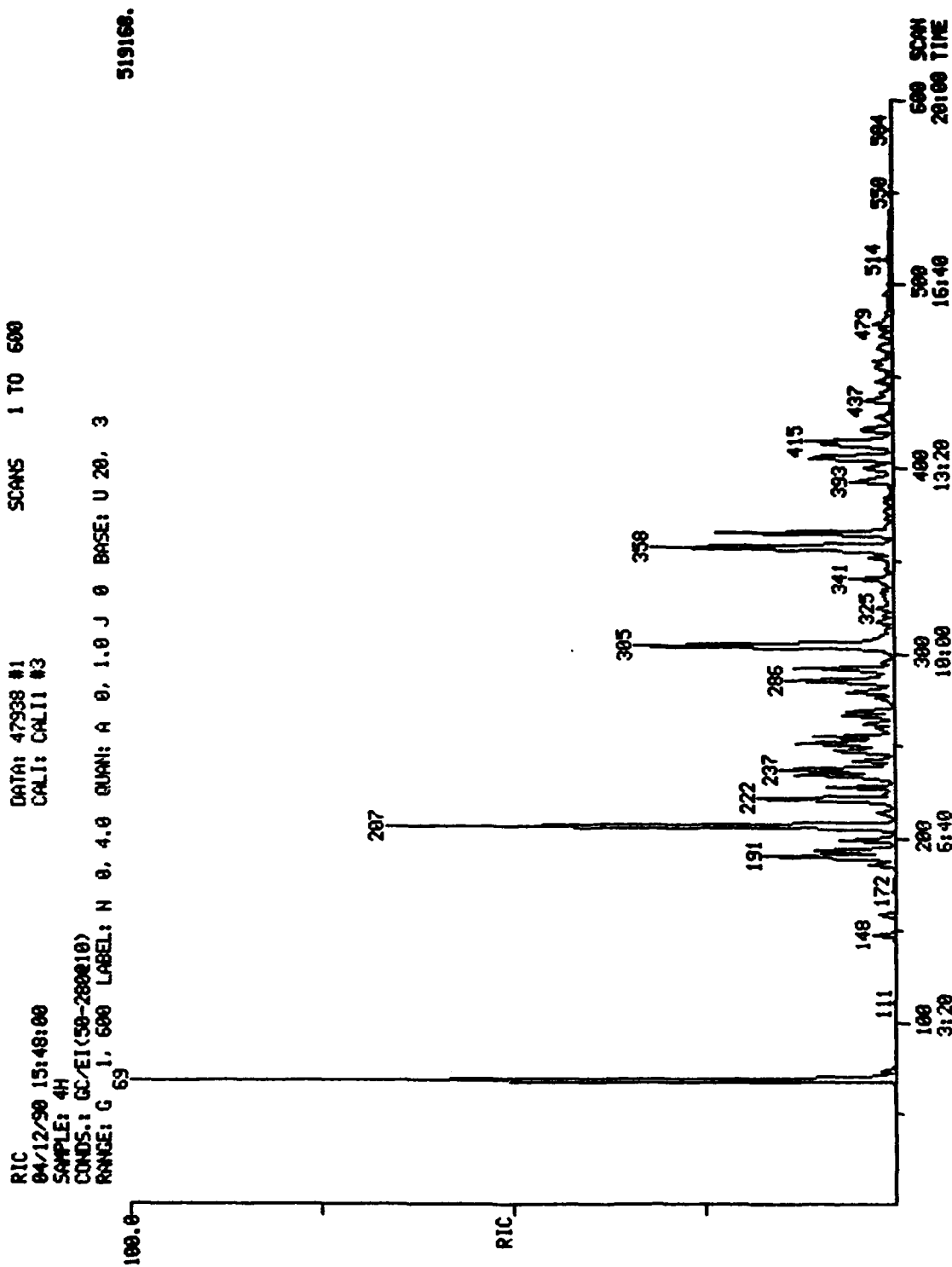


Figure 29. GC data for sample from IM8/HTA, tested at 350°F

Table 1. Specimen Identification Numbers

Sample ID	Sample No.	Figure No.
JP-4 Jet Fuel	JP-4-S3	24
JP-8 Jet Fuel	JP-8-S1	25
APC-2, RT test	ATP	26
APC-2, 250°F test	P5	27
HTA, RT test	3H	28
HTA, 350°F test	4H	29

Table 2. MS Analysis of JP-4

1	PENTANE, 2,3-DIMETHYL-	1	21.56
2	HEPTANE	0.83292	17.96
3	CYCLOHEXANE, MEHTHY-	0.6206	13.38
4	OCTANE	0.434	9.36
5	HEPTANE, 2,6-DIMETHYL-	0.0403	0.87
6	CYCLOHEXANE, ETHYL-	0.21854	4.71
7	OCTANE, 2-METHYL-	0.17664	3.81
8	BENZENE, 1,2-DIMETHYL-	0.2346	5.06
9	NONANE	0.44151	9.52
10	2-HEXENE, 3,4,4-TRIMETHYL-	0.1155	2.49
11	DECANE	0.31431	6.78
12	NONANE, 2,6-DIMETHYL-	0.08136	1.75
13	DECANE, 2-METHYL-	0.12723	2.74
TOTAL =		4.63751	100.00

Table 3. MS Analysis of JP-8

1	HEXANE, 2,4-DETHYL-	0.04292	0.93
2	OCTANE	0.06966	1.52
3	CYCLOPENTANE, (2-METHYLBUTYL)-	0.08735	1.90
4	OCTANE, 2-METHYL-	0.22423	4.88
5	NONANE	0.46047	10.03
6	2-HEXENE, 3,4,4-TRIMETHYL-	0.06362	1.39
7	3-HEXENE, 3-ETHYL-2,5-DIMETHYL-	0.18469	4.02
8	DECANE	1	21.78
9	NONANE, 2,6-DIMETHYL-	0.55229	12.03
10	DECANE, 3-METHYL-	0.98445	21.44
11	BENZENE, 2-ETHYL-1,3-DIMETHYL-	0.29627	6.45
12	UNDECANE	0.62465	13.61
TOTAL =		4.5906	100.00

Table 4. MS Analysis of sample from APC-2 (ATP), test at RT

1	PENTANE	1	17.27	1.02	1.73
2	ETHANOL, 2-METHOXY-	0.57076	9.86	0.58	0.99
3	OCTANE	0.154	2.66	0.16	0.27
4	CYCLOHEXANE, ETHY-	0.15023	2.59	0.15	0.26
5	BENZENE, 1,4-DIMETHYL-	0.5792	10.00	0.59	1.00
6	NONANE	0.42072	7.27	0.43	0.73
7	BENZENE, 1-ETHYL-2-METHYL-	0.41621	7.19	0.42	0.72
8	PHENOL	0.98473	17.00	1.00	1.70
9	BENZENE, 1,2,3-TRIMETHYL-	0.58725	10.14	0.60	1.01
10	BENZENE, 2-ETHYL-1,4-DIMETHYL-	0.29935	5.17	0.30	0.52
11	UNDECANE	0.18143	3.13	0.18	0.31
12	BENZENE, 1,2,3,5-TETRAMETHYL-	0.07	1.21	0.07	0.12
13	NAPHTHALENE, 1,2,3,4-TETRAHYDRO	0.07462	1.29	0.08	0.13
14	UNDECANE, 4,7-DIMETHYL-	0.0681	1.18	0.07	0.12
15	NAPHTHALENE, 2-METHYL-	0.15097	2.61	0.15	0.26
16	TETRADECANE	0.04117	0.71	0.04	0.07
17	NAPHTHALENE, 1,3-DIMETHYL-	0.04221	0.73	0.04	0.07
	TOTAL =	5.79095	100.00		

Table 5. MS Analysis of sample from APC-2 (P5), test at 250°F

1	BENZENE, METHYL-	0.01156	1.10	0.012	0.48
2	OCTANE	0.00157	0.15	0.002	0.07
3	BENZENE, 1,2-DIMETHYL-	0.02392	2.28	0.024	1.00
4	PHENOL	1	95.13	1.000	41.72
5	NAPHTHALENE	0.00482	0.46	0.005	0.20
6	NAPHTHALENE, 2-METHYL-	0.00672	0.64	0.007	0.28
7	NAPHTHALENE, 1,3-DIMETHYL-	0.00262	0.25	0.003	0.11
	TOTAL =	1.05121	100.00		

Table 6. MS Analysis of sample from IM8/HTA (3H), test at RT

1	BENZENE, METHYL-	0.18217	6.19	0.48
2	OCTANE	0.0301	1.02	0.08
3	CYCLOHEXANE, ETHYL-	0.01149	0.39	0.03
4	BENZENE, 1,4-DIMETHYL-	1.35899	46.15	3.58
5	2-HEXENE, 3,4,4-TRIMETHYL-	0.00529	0.18	0.01
6	BENZENE, (1-METHYLETHYL)-	0.04207	1.43	0.11
7	BENZENE, PROPYL-	0.05144	1.75	0.14
8	BENZENE, 1-ETHYL-3-METHYL-	0.38094	12.94	1.00
10	BENZENE, 1,2,4-TRIMETHYL-	0.43579	14.80	1.15
11	BENZENEACETALDEHYDE, ALPHA	0.00967	0.33	0.03
12	BENZENE, 1-PROPENYL-	0.02514	0.85	0.07
13	BENZENE, 1-METHYL-3-PROPYL-	0.11288	3.83	0.30
14	BENZENE, 2-ETHYL-1,4-DIMETHYL-	0.15189	5.16	0.40
15	BENZENE, 1-METHYL-2-(2-PROPENYL)-	0.01583	0.54	0.04
16	NAPHTHALENE, 1,2,3,4-TETRAHYDRO-	0.02456	0.83	0.06
17	1-BUTANOL,4-METHOXY-	0.10662	3.62	0.28
	TOTAL =	2.94487	100.00	

Table 7. MS Analysis of sample from IM8/HTA (4H), test at 350°F

1	BENZENE, PROPYL-	0.0531	1.05	0.09
2	BENZENE, 1-ETHYL-2-METHYL-	0.57643	11.39	1.00
3	BENZENE, 1,2,4-TRIMETHYL-	1.37284	27.13	2.38
4	BENZENE, (1-MEHTYLPROPYL)-	0.02791	0.55	0.05
6	BENZENE, 1-ETHENYL-2-METHYL-	0.08819	1.74	0.15
7	BENZENE, DIETHYL-	0.5118	10.11	0.89
8	BENZENE, 1-METHYL-3-PROPYL-	0.06324	1.25	0.11
9	BENZENE, 2-ETHYL-1,4-DIMETHYL-	0.778	15.37	1.35
10	BENZENE, 1-METHYL-2-(2-PROPENYL)-	0.15361	3.04	0.27
11	BENZENE, 1,2,3,4-TETRAMETHYL-	0.30516	6.03	0.53
12	NAPHTHALENE, 1,2,3,4-TETRAHYDRO	0.19796	3.91	0.34
13	NAPHTHALENE	0.93251	18.43	1.62
	TOTAL =	5.06075	100.00	